

CLAIMS

We claim:

1. A method for forming an inductor, comprising:
 - forming in a ceramic substrate a first plurality of conductive vias radially spaced a first distance from a central axis so as to define an inner circumference;
 - forming in said ceramic substrate a second plurality of conductive vias radially spaced a second distance about said central axis so as to define an outer circumference;
 - forming a first plurality of conductive traces disposed in a first plane defined orthogonal to said central axis, said first plurality of conductive traces forming an electrical connection between substantially radially adjacent ones of said first and second plurality of conductive vias;
 - forming a second plurality of conductive traces disposed in a second plane spaced from said first plane and defined orthogonal to said central axis to define an electrical connection between circumferentially offset ones of said first and second plurality of conductive vias to define a three dimensional toroidal coil.
2. The method according to claim 1 further comprising the step of firing said ceramic substrate after said conductive vias and said traces have been formed.
3. The method according to claim 2, further comprising the step of forming at least a toroid shaped core region of said ceramic substrate, defined within said toroidal coil, of a ceramic material having at least one electrical characteristic different from at least one other portion of said ceramic substrate.
4. The method according to claim 3, further comprising the step of selecting said electrical characteristic to be a permeability.
5. The method according to claim 4, further comprising the step of selecting said permeability of said toroid shaped core region to be greater than one.

6. The method according to claim 3 wherein said ceramic material is a low-temperature co-fired ceramic (LTCC) material.
7. The method according to claim 1, further comprising the step of forming said ceramic substrate by stacking a plurality of unfired ceramic layers, and selecting at least one of said unfired ceramic layers to have a permeability greater than one.
8. The method according to claim 7 further comprising the step of positioning said at least one ceramic layer having a permeability greater than one to be at least partially contained within a toroid shaped core region of said ceramic substrate, defined within said toroidal coil.
9. The method according to claim 1 further comprising the steps of :
 - forming a third plurality of conductive vias radially spaced a third distance from said central axis so as to define an second inner circumference, said third distance less than said first distance;
 - forming in said ceramic substrate a fourth plurality of conductive vias radially spaced a fourth distance about said central axis so as to define a second outer circumference, said fourth distance larger than said second distance;
 - forming a third plurality of conductive traces disposed in a third plane defined orthogonal to said central axis, said third plurality of conductive traces forming an electrical connection between substantially radially adjacent ones of said third and fourth plurality of conductive vias;
 - forming a fourth plurality of conductive traces disposed in a fourth plane spaced from said first plane and defined orthogonal to said central axis to define an electrical connection between circumferentially offset ones of said third and fourth plurality of conductive vias to define a second three dimensional toroidal coil.
10. The method according to claim 9 further comprising the step of forming an electrical connection between the first and second three-dimensional conductive toroidal coils.

11. The method according to claim 10 further comprising the step of configuring said electrical connection so that the first and second toroidal coils generate a magnetic field in a common direction.

12. An inductor, comprising:

- a first plurality of conductive vias formed in a ceramic substrate radially spaced a first distance from a central axis so as to define an inner circumference;

- a second plurality of conductive vias radially spaced a second distance about said central axis so as to define an outer circumference;

- a first plurality of conductive traces disposed in a first plane defined orthogonal to said central axis, said first plurality of conductive traces forming an electrical connection between substantially radially adjacent ones of said first and second plurality of conductive vias;

- a second plurality of conductive trace disposed in a second plane spaced from said first plane and defined orthogonal to said central axis, and forming an electrical connection between circumferentially offset ones of said first and second plurality of conductive vias to define a three-dimensional conductive toroidal coil.

13. The inductor according to claim 12 wherein said ceramic substrate is formed of a material compatible for cofiring with said conductive vias and said conductive traces.

14. The inductor according to claim 13, wherein at least a toroid shaped core region of said ceramic substrate, defined within said toroidal coil, is formed of a ceramic material having at least one electrical characteristic different from at least one other portion of said ceramic substrate.

15. The inductor according to claim 14, wherein said electrical characteristic is permeability.

16. The inductor according to claim 15, wherein said permeability of said toroid shaped core region is greater than one.
17. The inductor according to claim 14 wherein said ceramic material is a low-temperature co-fired ceramic (LTCC) material.
18. The inductor according to claim 12, wherein said ceramic substrate is comprised of a cofired stack of ceramic layers, and at least one of said ceramic layers has a permeability greater than one.
19. The inductor according to claim 18 wherein at least one ceramic layer having a permeability greater than one is positioned at least partially contained within a toroid shaped core region of said ceramic substrate defined within said toroidal coil.
20. The inductor according to claim 12 further comprising terminal connections located at opposing ends of said toroidal coil.
21. The inductor according to claim 12 further comprising:
 - a third plurality of conductive vias formed in a ceramic substrate radially spaced a third distance from said central axis so as to define a second inner circumference, said third distance less than said first distance;
 - a fourth plurality of conductive vias radially spaced a fourth distance about said central axis so as to define a second outer circumference, said fourth distance larger than said second distance;
 - a third plurality of conductive traces disposed in a third plane defined orthogonal to said central axis, said third plurality of conductive traces forming an electrical connection between substantially radially adjacent ones of said third and fourth plurality of conductive vias;
 - a fourth plurality of conductive traces disposed in a fourth plane spaced from said third plane and defined orthogonal to said central axis, and forming an electrical connection between circumferentially offset ones of said third and fourth plurality of

conductive vias to define a second three-dimensional conductive toroidal coil.

22. The inductor according to claim 21 further comprising an electrical connection between the first and second three-dimensional conductive toroidal coils.

23. The inductor according to claim 22 further wherein said at least one electrical connection causes said first and second toroidal coils to generate a magnetic field in a common direction.

24. A printed circuit board, comprising:
a ceramic substrate;
a ceramic toroidal core embedded within said ceramic substrate; and
a conductive coil comprising a plurality of turns about said ceramic toroidal core, wherein said ceramic toroidal core is integrally formed with said ceramic substrate in a co-firing process.

25. The printed circuit board according to claim 24 wherein said plurality of turns are contained within said ceramic substrate at all points.

26. The printed circuit board according to claim 24 wherein said ceramic toroidal core is comprised of a ceramic material that has a permeability greater than a second ceramic material comprising at least one other portion of said ceramic substrate.

27. The printed circuit board according to claim 24 further comprising at least one conductive metal ground plane layer disposed within said ceramic substrate.

28. The printed circuit board according to claim 27 wherein said ground plane layer is interposed between said conductive coil and at least one surface mount component disposed on said printed circuit board.

29. The printed circuit board according to claim 24 wherein said conductive coil has a

plurality of winding layers, each winding layer defining a toroidal coil disposed about said ceramic toroidal core and having a coil radius different from an adjacent winding layer.

30. A method for forming an inductor in a ceramic substrate, comprising the steps of:
forming a conductive coil comprising a plurality of turns about an unfired ceramic toroidal core region defined within an unfired ceramic substrate; and
co-firing said ceramic toroidal core region, said ceramic substrate, and said conductive coil to form an integral ceramic substrate structure with said conductive coil at least partially embedded therein.

31. The method according to claim 30, further comprising the step of forming said ceramic toroidal core region of a ceramic material having a permeability greater than one.

32. The method according to claim 30 further comprising the step of disposing a conductive ground plane layer between said conductive coil and an outer surface of said ceramic substrate.

33. The method according to claim 30 further comprising the step of forming said conductive coil with a plurality of winding layers, each winding layer defining a toroidal coil disposed about said ceramic toroidal core and having a coil radius different from an adjacent winding layer.

34. A toroidal inductor, comprising:
a ceramic substrate;
a ceramic toroidal core embedded within said ceramic substrate; and
a conductive coil comprising a plurality of turns about said ceramic toroidal core, wherein said ceramic toroidal core is integrally formed with said ceramic substrate in a co-firing process.